

**INFORMATION SHARING DURING EMERGENCY RESPONSE AND RECOVERY:
A FRAMEWORK FOR ROADING ORGANISATIONS**

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ABSTRACT

Roading organizations are involved in a wide range of emergency response and recovery activities. Information sharing is a critical element in deploying roading organisation resources during emergency response and recovery activities. This paper presents an information sharing framework for roading organizations. Based on the study of response and recovery activities, information needs were identified and a GIS-based information sharing framework was created. The framework is applied to a desktop case study in the South Island of New Zealand to establish the approximate magnitude of potential benefits. Results show that a potential reduction in time and cost of emergency response activities could be reached if the conceptual framework was implemented through reduced response times, faster access to relevant information and therefore enhanced decision making.

INTRODUCTION

1 Rooding organizations are involved in a wide range of emergency response and
2 recovery activities. Diverse damage magnitude events such as car accidents, snow storms,
3 flooding, earthquakes, and volcanic eruptions may affect rooding assets and disrupt the road
4 network throughout the country. Local, regional and national rooding organizations conduct
5 response and recovery activities, which involve the deployment of resources to minimize the
6 disruption of road closures to society,

7 Information sharing is a critical element in deploying rooding organisation resources
8 during emergency response and recovery activities. Without collecting, collating and
9 communicating data and information among multiple organizations, damage may not be
10 properly assessed and resources may not be adequately deployed, which may cause inefficient
11 coordination and decision-making ^{(1) (2)}. According to the efficiency levels of information
12 sharing, even a small event such as a car crash may either result in a short or long road closure.
13 On the other hand, an earthquake event, for example, requires intensive exchange of damage
14 and resource deployment information that may save lives and reduce disruption. These
15 complexities emphasise the need to develop robust yet simple frameworks for sharing
16 information and communicating decisions within and between organizations involved in
17 response and recovery activities.

18 Although it is widely acknowledged the importance of information sharing during
19 emergency events, current practices and techniques present considerable limitations in
20 providing tools that fulfil the needs of emergency management practitioners. Technological
21 advances in information management of spatial-temporal data such as Geographical
22 Information Systems (GIS) have been made in recent years ^{(3) (4) (5) (6) (7)}. Nevertheless, after
23 studying various implementations of GIS in emergencies, Zerger ⁽⁸⁾ concludes that most case
24 studies do not have a real-time capability and require events to be pre-modeled. According to
25 the National Research Council ⁽⁹⁾“...experience has shown that it is critical, in applying IT to
26 disaster management, to start with real problems faced by real end users, to find solutions,
27 and then to work back from there to overarching themes. Starting with overarching themes
28 will lead to dead-ends, and unimplemented and un-implementable technology...”.

29 This paper takes an end-user centric approach rather than a platform centric approach
30 in the design of an information sharing framework for New Zealand rooding organizations. In
31 the light of information management concepts and principles, the framework is the result of
32 conducting comprehensive analyses of the nature and background of involved organizations;
33 the characteristics of their involvement; their data/information needs; their data/information
34 sharing needs; and how organizations could/should share data and information. After this
35 brief introduction, the emergency management context in New Zealand is described. The third
36 section summarizes the role of rooding organizations during emergency events. The
37 information sharing framework comprising a series of steps for information acquisition,
38 storage and sharing during emergency events is introduced in the fourth section. The
39 framework is applied to a desktop case study in the South Island of New Zealand to establish
40 the approximate magnitude of potential benefits. Finally the sixth section discusses the main
41 findings of this research, as well as recommendations for further studies.

EMERGENCY MANAGEMENT IN NEW ZEALAND

In New Zealand, the Ministry of Civil Defence and Emergency Management (MCDEM) is a semi-autonomous body within the Department of Internal Affairs. MCDEM has over-arching responsibility for developing and maintaining the preparedness of the New Zealand community for any natural and technological hazards or disasters⁽¹⁰⁾. Created in 1999 from the former Ministry of Civil Defence, MCDEM also provides policy advice to the Government⁽¹¹⁾.

In 2002, the Civil Defence Emergency Management Act established a national and regional framework in which an emergency management strategy and plan were adopted. One of the features of the Act is the establishment of CDEM Groups based on regional council boundaries, and the requirement that a risk management-based approach be adopted. CDEM Groups are consortia of local authorities, emergency services and health boards in each region.

The CDEM Act (2002) requires every local authority to plan and provide for Civil Defence and Emergency Management (CDEM) within its district, and to ensure that it is able to function to the fullest possible extent, even though this may be at a reduced level, during and after an emergency. One of the features of the Act is that this requirement also applies to lifeline utilities and central government departments. MCDEM works in coordination with local and regional governments, utilities and the emergency services involved in CDEM. MCDEM's Director acts as Chief Executive of the Ministry in its day-to-day operations. In cases of national emergencies, the Director has special powers defined in the legislation.

In the event of a Civil Defence Emergency declaration, the CDEM Group (or local Civil Defence Controller co-ordinates the response and makes decisions about key response actions after communication and consultation with the emergency services, health agencies and key lifeline organizations. The regional and national CDEM Emergency Operations Centres (EOCs) interact with these organizations to facilitate and support decisions on prioritization of response activities. Relevant data/information from all the above organizations is expected to be shared with CDEM agencies to facilitate decision making.

ROADING ORGANIZATIONS AND EMERGENCY RESPONSE IN NEW ZEALAND

New Zealand has about 10 thousand kilometres of State Highway network. These roads are a national asset worth approximately NZ\$12 billion and Transit New Zealand (NZ) is responsible for maintaining and enhancing these assets. 56% of the annual budget is allocated for the maintenance and rehabilitation of existing roads⁽¹²⁾.

Typically, Transit NZ appoints Consultants to undertake technical services to determine work requirements according to Transit NZ Regional office's directives, and Contractors for carrying out the physical works⁽¹³⁾. The State Highway network is divided into seven regions, each with their own Consultant and Contractor arrangements.

This structure provides the State Highway network with some resilience during emergencies in that many of these Consultants and Contractors are national or sometimes even international organizations. This means that resources can be brought in from other areas to boost resources available to an affected region during the crisis. However this structure also adds complexity that needs to be recognised and managed. As the number of organizations involved in effecting response and recovery increases, particularly if an emergency spans more than one region, communication and sharing of information within and between organizations becomes more complex to manage.

The Transit NZ emergency response process can be divided into 6 core elements, these are: (1) **event warning**; (2) **event observation**; (3) **event assessment**; (4) **organisation action**; (5) **organisation reporting**; (6) **organisation re-evaluation**. During re-evaluation

1 (6), the outcomes are used to decide whether the response is considered over or should be
2 continued from event assessment (3). The dynamic nature of emergency response is such that
3 many elements of the response process are conducted simultaneously and as the event
4 develops, the appropriateness of different response strategies needs to be constantly re-
5 evaluated.

6 In each stage of the response process, different organisations are involved. In the event
7 warning phase, external organisations such as research institutes, meteorological services,
8 regional and local councils etc provide initial warnings and updates of potential events.
9 During or after the event (event observation phase), the Contractor along with external
10 organisations and the public verify initial damage caused to the transportation system
11 (pavement and bridge collapses, obstruction of lanes, etc.). Depending on the extent of
12 damage, these conditions are reported to the Consultant, Transit NZ, Local Road Controlling
13 Authorities, the emergency services and other lifeline organisations, or if a Civil Defence
14 Emergency has been declared, the regional or national CDEM EOC. In the subsequent phase
15 (event assessment), again depending on the type of the emergency, all the above organisations
16 except external organisations and the public are involved. Organisation action involves the
17 same organisations deploying their physical and personnel resources according to their
18 response responsibilities. Most of the field operation is conducted by the Contractors in small
19 and medium events.

20 In large events the CDEM Controller, lifeline organisations and Local/Regional
21 Authorities are also involved. These actions are supervised by the Consultant and Transit NZ.
22 As part of organisation reporting, the Contractor, CDEM, Local/Regional Authorities and
23 lifeline organisations describe current road conditions after the initial round of measures and
24 any further development of the original event (better information about damage, more events,
25 etc.). These reports are then taken into consideration during organisation re-evaluation, in
26 which the organisation evaluates the measures taken and their efficiency. Finally, decisions
27 are made as to whether to continue or stop response activities depending on the efficiency
28 assessment. If a decision is made to continue, the process restarts again from event assessment.

29 Emergency situations are classified by Transit NZ into 3 levels according to the time
30 required for road reopening: small (a specific part/segment of the State Highway network is
31 affected for an approximate duration less than 6 hours), medium (multiple parts/segments of
32 the State Highway network are affected for up to a day) and large events (severe damage to
33 the State Highway Network, other lifeline infrastructure systems and life threatening
34 situations are observed, prompting Civil Defence to dictate response and recovery priorities)
35 (13).

36 Organizations involved in response and recovery activities need a large variety of
37 information. In order to act in a coordinated and effective way organizations require access to
38 data and information characterizing the disaster's intensity, location and related damage, as
39 well as the availability of human and physical resources. Organizations will have their own
40 particular information needs, which may be different for each level in the organisation. For
41 example, Transit NZ Headquarters' personnel in Wellington will need general road closure
42 information such as summary of damage, expected opening, forecasted recovery cost, etc. On
43 the other hand, the Transit NZ network engineer will need access to much more specific
44 information about damage, work progress, costs and resources availability. Based upon the
45 available information, both sections will make their decisions on allocating the resources over
46 time and space.
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AN EMERGENCY RESPONSE INFORMATION SHARING FRAMEWORK FOR NEW ZEALAND ROADING ORGANIZATIONS

This framework was developed following the concepts of knowledge and information management ⁽¹⁴⁾. The first step in the process was to identify the information needs of the organizations involved in response. This was done by examining Transit NZ's emergency procedures and reports and translating these using the Integrated DEFination (IDEF0) modeling language (semantics and syntax) ⁽¹⁵⁾, into a summary of information needs and sources during each phase of the response and recovery effort (Table 1).

These information needs were then considered in the conception of the data/information sharing framework that is presented in Figure 1. The framework utilizes Transit NZ's current inventory database to generate a Dynamic Geographic Information System (DGIS) for emergency response. Transit NZ's inventory database (RAMM), comprises historic data on roading assets and their condition over time. In an emergency response event, the framework proposes that data from RAMM is dynamically retrieved, organized and distributed amongst Consultants, Contractors and Transit NZ using the DGIS. The data/information framework establishes the linkages, templates and sharing standards to enable the conversion of road maintenance data (RAMM) into information required during emergency response activities (*DGIS*).

For example, during an emergency event with warning (e.g. flooding), the framework (see Figure 1) is applied following the steps below:

- Preliminary information (arrows **A** and **B**) on the potentially damaged region and assets is used by Transit NZ, Consultants and Contractors in generating data/information related to the potential emergency using RAMM (**C**) and emergency response resources are placed on alert (**D**);
- The relevant information is then extracted from RAMM by the Consultant (**E**) and linked to maps using the *DGIS*;
- During and after the hazard event, Contractors receive information from the police and the public about road closures and damage;
- Using data from *DGIS* (**G**), the Contractors perform an *in situ Initial Assessment* comparing observed conditions with pre-event roading characteristics (e.g. bridge abutment collapsed, signpost missing);
- The observed conditions (**H**) are summarized and **Reported** back to the Consultant via the *DGIS* database (**J**);
- The Consultant retrieves data on the damaged assets (**K**) and considering available resources a **Treatment Decision** is made (**L1**) and shared with the Contractor (**L2**);
- The Contractor **Deploys Resources** to implement the treatment; actual resource deployment is recorded (**M**) into the *DGIS* database;
- After the completion of the work, the Contractor compares before/after event conditions (**N**) and conducts a **Results Reporting**, which is subsequently recorded (**P1**) into *DGIS*;
- The Consultant retrieves data (**P2**) and conducts an **Efficiency Assessment** in which either the response is finalized (road opening - **Q**) or continued (**R**); and
- If the response is continued, the Consultant re-starts the process from the **Treatment Decision** phase.

Table 1. Transit NZ and response partners' information needs in response activities

	Regional Consultant info needs	Regional Contractor info needs	Transit NZ Regional Office info needs	CDEM Group info needs
Event Occurrence		<ul style="list-style-type: none"> -Potential damaged area/region -Type of event -Intensity and expected duration -Available resources 		
Event Observation	<ul style="list-style-type: none"> -Damaged area/region -Type of event -Damaged asset type -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors' resources -CD emergency declaration? 	<ul style="list-style-type: none"> -Damaged area/region -Type of event -Attributes of potentially damaged assets (location; original condition; characteristics; costs; priority repair availability). 	<ul style="list-style-type: none"> -Damaged area/region and event type -Damaged asset type; -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors/Consultants' available resources -Initial road closure time/ costs estimation -MCDEM emergency declaration? 	
Event Assessment	<ul style="list-style-type: none"> -Comparison before and after / damaged asset Location Original condition Characteristics Treatment options Costs Priority Repair availability -Contractors' available resources 		<ul style="list-style-type: none"> -Report on before and after / damaged asset -Summary of damaged assets per type -Summary of treatment options -Summary of Costs/Priorities Repair availability -Consultants and contractors available resources -Initial road closure time estimation -Initial cost estimation -MCDEM emergency declaration? 	<ul style="list-style-type: none"> -Report on road closures (Location; Partial/complete; Expected road opening -Consultants and contractors available resources -Initial cost estimation
Resources Deployment	<ul style="list-style-type: none"> -Location of Contractors' equipment and personnel -Deployment times -Allocation plan of resources and personnel per damaged asset (location; original condition; characteristics; treatment; priority; effectiveness) -Traffic management plan MCDEM emergency declaration? 	<ul style="list-style-type: none"> -Allocation plan of resources and personnel per damaged asset (location; original condition; characteristics; treatment; priority; effectiveness) -Deployment times -Traffic management plan MCDEM emergency declaration? 		
Event Reporting	<ul style="list-style-type: none"> Damaged area/region -Attributes of damaged assets: (location; original/current conditions; characteristics; treatment; costs; priorities; repair availability) 	<ul style="list-style-type: none"> Damaged asset type Attributes of damaged assets: (location; original/current conditions; characteristics; treatment; costs; priorities; repair availability) -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors' available resources 	<ul style="list-style-type: none"> -Damaged asset type -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors/Consultants' available resources -Road closure time/costs estimation -MCDEM emergency declaration? 	
Event Re-assessment	<ul style="list-style-type: none"> -Comparison before and after / damaged asset (location; original condition; characteristics; treatment options; costs; priority; repair availability) -Contractors' available resources Stop response/Initiate Recovery mode/Continue Response? 		<ul style="list-style-type: none"> -Report on before and after / damaged asset -Summary of damaged assets per type, treatment options, Costs and Priorities -Repair availability -Consultants and contractors available resources -Initial road closure time cost estimation -Stop response/Initiate Recovery mode/Continue Response? -MCDEM emergency declaration? 	<ul style="list-style-type: none"> -Report on road closures (Location; Partial/complete; Expected road opening -Consultants and contractors available resources -Initial cost estimation

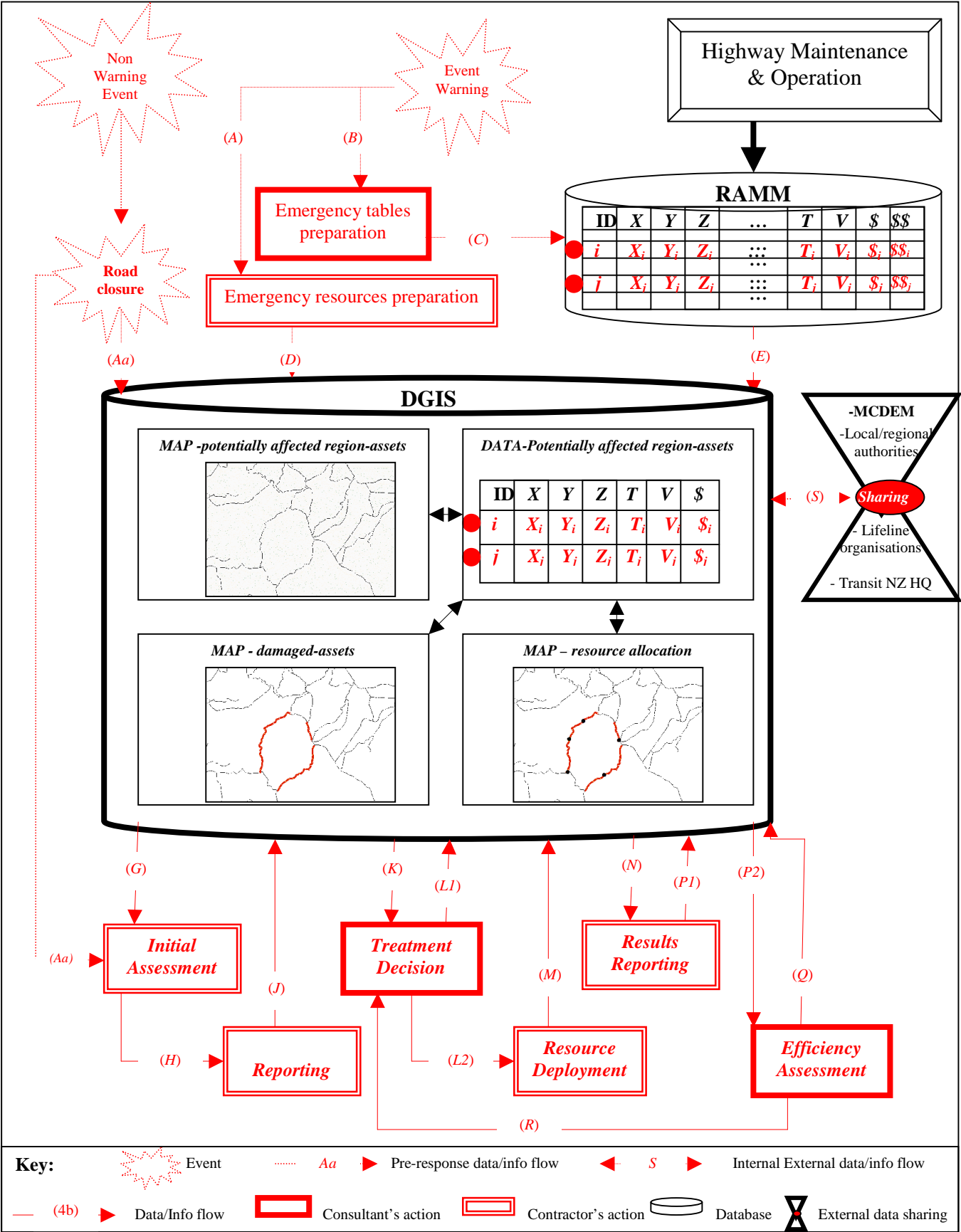


Figure 1 –Data/Information framework for roading organisations

During all the response phases, data is simultaneously shared with all other involved organisations (S). These organisations also input new information which is shared among Transit NZ's Consultants and Contractors. Transit NZ regional engineers can either act as observers for small events or become involved with the decision making process. For events without warning (e.g. car accidents; earthquakes; etc), the same phases are followed except for the initial preparation (emergency tables preparation and emergency resources preparation).

CASE STUDY

This proposed information sharing framework was applied in a desktop case study in the South Island of New Zealand to establish the approximate magnitude of potential benefits. This section describes the implementation issues and a comprehensive analysis in terms of cost (NZ\$) and time (minutes) of response activities with and without the data/information framework.

This case study is divided into 4 sub-sections. The first sub-section introduces the study area and the data sources and types used for the case study. In the second sub-section, the information sharing framework is applied to a road closure example. The third sub-section presents the estimation and analysis of time and cost for road closure reopening, for current practices (without data-information framework) and with the proposed framework.

Study area and data sources

The case study comprises of road closures in the South Island of New Zealand. The South Island occupies 151,215 square kilometers and consists of approximately 5000 Kilometers of State Highway network. The roading organization responsible for the maintenance of these State Highway network is Transit NZ which has divided the South Island into regions. South Island is divided into six regions namely North Canterbury, South Canterbury, West Coast, Coastal Otago, Central Otago and Southland. Each region has a contractor and a consultant for the construction and maintenance of the State Highways on contractual bases. During the duration of the case study, Opus International Limited (Opus) had the contract for consultation with Transit NZ for all these regions except Coastal Otago.

The road closure data used for applying the data/information framework is obtained from Opus International Limited's office in Greymouth where all the road closures in the South Island of New Zealand are stored. The database comprises information such as closure date, closure time, open date, open time, State Highway (SH), Route Station (RS), Route Position (RP), Location, closure type, closure reason, comments, region, road closed by, etc. The total road closures recorded during the 1 year period (April 2004 to March 2005) are 113. Figure 2 shows a GIS map (*GeoMedia Professional*) with the road closures categorized as per the road closure type.

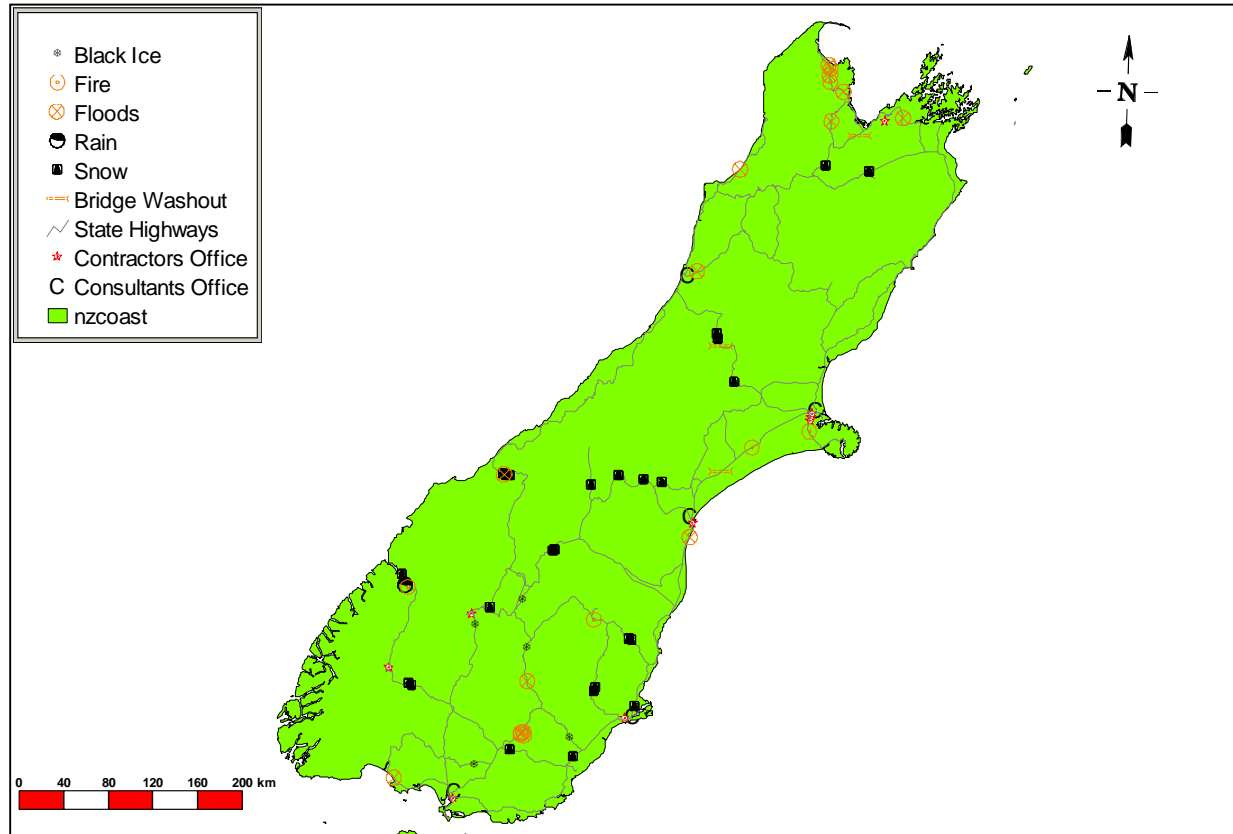


Figure 2 –Road closures categorized as per the road closure type.

Information sharing framework is applied to a road closure example

The information sharing framework is applied to a road closure that occurred on Saturday, 8th January 2005 at 5.00 am. The road between Tapanui and Gore (Pomehaka Bridge) was closed by the contractor due to flooding. The road was reopened after 37 hours, 40 minutes, on 9th January 2005 at 18:40:00 hours. Each of the response phases using the data/information framework is explained below:

- Using warning from MetService, RAMM database and *DGIS* maps are selected for the potentially damaged areas;
- The consultants retrieve the data from RAMM and export it to *DGIS*. The map showing the roads likely to be damaged and other features on the road like, signs, bridges, etc., and their exact location is displayed on the map along with their attributes like signpost ID, type of signpost, foundation, bridge name, length, etc;
- When the disaster occurs, the contractors go on site while the consultants fill in the details in emergency response form. This data is then shared with the other roading organizations and Civil Defence. The contractor accesses this information using a PDA or cell phone with mapping facilities;
- Once the contractor reaches the road closure site, the actual damage on the site is examined and then updated in the *DGIS* and shared with the consultants and other roading organizations;
- The consultants then assess the damaged condition based on the data/information provided by the contractor in *DGIS* and make decisions about the treatment to be given and prioritization of the work. The decision is made and shared in *DGIS* by the consultants. The contractors do the repair as per the instructions given by the consultants or the Civil Defence;

- After the repair is conducted, the contractor reports back to the consultants the condition of the road after repair. The condition of the bridge and the reinstallation of the signpost are reported back on *DGIS*; and
- The consultants then decide if the repair is done or the work is to be continued. After all the repair work is conducted, the road is reopened to traffic.

Assessment of time and cost saving using data/information framework

To estimate the amount of time and cost saved using the data/information framework, the time and cost of disaster response using current practice and using data/information framework is calculated. As only the total time for disaster response is available from the road closure data, it is subdivided into time periods for each phase using a set of assumptions. Also, the road closure costs are assessed based upon road traffic and time of closure (AM or PM).

A road closure event e that had a Response Time (RT_e) and is classified according to its type (Y) and emergency level (EL). Each event is also associated with a set of response phases p where, external agency or police contact consultants ($p=1$); consultants contact contractors ($p=2$); contractors reach the disaster affected site ($p=3$); contractors inform consultants of actual site condition ($p=4$); decision made on the treatment by contractors and consultants ($p=5$); Wait till condition suitable for repair or to get orders from MCDEM ($p=6$); repair done ($p=7$); and report to consultants ($p=8$). Combining all the data, each event (e) has been described as in Equations 1, 2, 3 and 4.

$$e = \{ Y; EL; \text{ and } t_{EL,y}^p \} \quad (\text{eq. 1})$$

$$EL = \begin{cases} 1; & \text{if } (RT_e < 6 \text{ hours}) \\ 2; & \text{if } (6 \leq RT_e < 24 \text{ hours}) \\ 3; & \text{if } (RT_e \geq 24 \text{ hours}) \end{cases} \quad (\text{eq.2})$$

$$ART_e[EL; Y] = \sum_{p=1}^8 AT^p[EL; Y] \quad (\text{eq. 3})$$

$$AT^p[EL; Y] = \frac{\sum_{e=1}^n t^p[EL; Y]}{n[EL; Y]} \quad (\text{eq. 4})$$

Where,

$ART_e[EL; Y]$ = Average time for road reopening for an event e , level EL and type Y ;

$AT^p[EL; Y]$ = Average time for each phase p and emergency level EL and type Y .

t^p = time for each phase p for each event e ;

n = number of event of same type Y and same emergency level EL .

In order to partially assess the efficiency of the information sharing framework, the travel delay costs to road users are estimated. The Average Cost of the road closure (AC) is dependent on the type of road closure, the level of emergency and the response phase duration. The total cost of a road closure is the summation of all costs for each phase, which is given in Equation 5.

$$CP_e^p = t_{(EL;Y)}^p \times \frac{AC^e}{ART_e} \quad (\text{eq. 5})$$

Where,

AC^e = Average cost of road closure for total time of road closure to the user; and

ART_e = Average road reopening time for a road closure event e for an emergency level EL and type Y .

CP_e^p = Cost per phase p for an event e ;

$t_{(EL;Y)}^p$ = time for phase p for an emergency level EL and type Y ; and

The implementation and operation of the data/information framework is expected to reduce the response duration for some of the phases. There may not be any change in time for some phases; however the overall time is very likely to be reduced. For each phase, potential reduction can be achieved by adopting the following measures:

- Phase 3 (time taken for contractor to reach the site): This time can be reduced if the contractor has a GIS map showing the exact location of the road closure site. The amount by which this time is reduced may be assumed to be between 1 to 5 % of the original time;
- Phase 4 (contractor informs the consultant the actual site condition): This time can also be reduced using the information framework by 1 to 5% because the contractor has the details of the road site in DGIS;
- Phase 5 (decision making stage on the treatment to be given): time can be reduced by 10 to 15%, since all the data/information is available for the decision to be made quickly;
- Phase 6 (waiting time for the orders from Civil Defence in case of large events): time for this phase can be assumed to be reduced by 10 to 15%, since the Civil Defence will have the GIS maps and the required information based on which the decision may be made faster than current practice;
- Phase 7 (the time taken to do the repair work): time may be reduced by 1 to 5% if the contractor has the map of the existing road features, etc before the road closures; and
- Phase 8 (consultants can report back to the Civil Defence and the contractors of the condition after the repair): it can be reduced by 1 to 5% with the use of the framework.

Based on these assumptions, 3 scenarios are created as summarized in Table 2. For scenario 1, the durations of 1 and 2 are not reduced but 3, 4, 7 and 8 are reduced by 2.5% and phases 5 and 6 are reduced by 12.5%. For scenario 2 (best case scenario) the durations for phase 1 and 2 are not reduced, but phases 3, 4, 7 and 8 are reduced by 5% and phases 5 and 6 are reduced by 15%. Finally, for scenario 3, (worst case scenario) the durations for phase 1 and 2 are not reduced. The durations for phase 3, 4, 7 and 8 are reduced by 1% and for phase 5 and 6 are reduced by 10%. The percentage reduction in time is applied to all the phases for the three scenarios to calculate the reduction in time. The cost for the 3 scenarios is found by calculating the proportional cost for the reduced time as compared to the original time. The results of the average time and cost for all scenarios are in Table 2.

The total cost of road closures per year is estimated to be approximately 3 million dollars. By using the data/information framework, the cost of road closures can be reduced up to 2.7 million dollars. The best case scenario (scenario 2) would generate 5.53% (NZ\$ 162,342) reduction while the worst case scenario (scenario 3) would generate a reduction of 1.70% (NZ\$ 49,952).

The analysis of road closures reveals that slip events cause the highest costs (NZ\$181,849) for the current practice (business as usual). With the use of data/information framework, cost reduction could range between 5.89% and 2%. The annual cost of road

closure due to flooding, snow and accidents is also high and considerable reduction in the cost of these road closures may be achieved in Scenario 2. For small emergencies, the maximum cost of road closures is due to accidents. On one hand, this may be because from the 113 road closures recorded for 1 year (from April 2004 to March 2005), 29 road closures are due to small accidents. On the other hand, it could also be because all the road closures due to accidents that do not have an initial warning which means that the consultants and contractors may not be well prepared for the response and the accidents mostly occur on roads with high traffic flow thus causing delay to more users.

Table 2 – Case study scenarios and their respective annual costs

		Percentage of time reduced for each phase (%)								Annual Cost (NZ\$)	Reduction (NZ\$)	Reduction (%)
		p=1	p=2	p=3	p=4	p=5	p=6	p=7	p=8			
Scenarios	Business as usual	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2933331	0	0
	1	0.0	0.0	2.5	2.5	12.5	12.5	2.5	2.5	2839672	93659	3.19
	2	0.0	0.0	5.0	5.0	15.0	15.0	5.0	5.0	2770989	162342	5.53
	3	0.0	0.0	1.0	1.0	10.0	10.0	1.0	1.0	2883379	49952	1.7

End-users feedback and pathway to implementation

The case study results were subsequently presented to our end-users. The research team has produced a first prototype version that focuses in graphically representing how the framework would be deployed during emergency. End-user organisations (Transit NZ and its consultants and contractors) were encouraged to participate and contribute to refine and assimilate the research findings. Initially, an end-user oriented report was compiled in order to review and summarize the critical issues involved in implementing electronic data and information sharing frameworks. The report (Dantas *et al*, 2006) written in a non-academic style, highlighted challenges, barriers and opportunities in the implementation of the information sharing framework. Copies of the report have been distributed and gradually feedback has been obtained from the end-users organisations. Other initiatives were workshops and return visits to the Transit NZ regional offices. During these meetings, the research team presented the DGIS vision, which was expressed in a series of “cartoon” presentations that graphically showed how DGIS would be employed in different emergency response scenarios. These presentations allowed the end-users to visualize and comment on the research findings. The key issue in facing this challenge was to adapt the research team’s reporting and presentation approach in order to reach and communicate according to end-users expectations and background.

CONCLUSION

The challenges involved in coordinating an effective response to emergency events are compounded by the number and variety of organisations involved. These complexities emphasise the need to develop robust yet simple frameworks for sharing information and communicating decisions within and between organisations involved in response and recovery activities. Considerable opportunities lie in exploring new paradigms for emergency response with extensive telecommunications and geo-spatial technologies. Greater focus, however, is needed in defining data/information sharing requirements and how the characteristics of the organisations involved affect implementation. A major outcome of this research is that perceived barriers can be reduced if technology is employed according to an

organisation's needs rather than the other way around. This is possible by involving end-users during all development stages of the electronic data and information sharing framework to develop a framework that complements the organisational structures, cultures and existing interfaces between the organisations involved.

This paper has shown the potential in adopting an information sharing framework to improve emergency response. Due to its simplicity and adequacy to current practices and procedures, it is very likely that the data/information framework could be applied to all the emergency types and emergency levels for response action by the roading organizations in New Zealand. Furthermore, the framework could also be applied to other countries considering their legal and institutional framework of the roading organizations.

Two main limitations can be identified in this research work. Firstly, the information sharing framework and the DGIS software have not been implemented and applied yet. Another limitation is quality and availability of road closure information. This has affected accuracy of the time and cost reductions after the implementation of the DGIS. Nevertheless, these limitations do not affect the validity of our findings, because an initial research effort has been made to demonstrate the potential of conceiving a customized tool for data/information sharing during emergency events.

The main area of further research would be the development of the data/information prototype in DGIS and its implementation on a real road closure. The DGIS can be developed using the principles of data sharing in GIS. The development of the prototype could be implemented in a real emergency situation and tested for its efficiency and applicability.

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